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Effect of Inclusion of Salmon Roe on Characteristics of Salmon Baby Food Products

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ABSTRACT: Baby food was formulated from sockeye salmon (puree alone, puree + chunks, puree + pink row, puree + pink row + chunks, puree + red row, puree + red roe + chunks). In the 1st study, physical (pH, instrumental color, water activity) and descriptive sensory (odor, flavor, texture, visual color) characteristics were determined. Samples containing roe were lighter and less red (by approximately 3 to 4 a^* units) than formulations without roe regardless of the type of roe added. Visual pink color followed the same trend. Formulations with roe, both pink and sockeye, were almost twice as fibrous as formulations without roe. Salmon flavor was stronger in samples containing roe from sockeye salmon. In the 2nd study, retort processed samples were stored at room temperature for 6 mo. Sweaty odor decreased over storage time. Visual cream-brown color correlated with L^*, a^*, b^*, and chroma values ($r = -0.80$, 0.75, 0.80, and 0.84, respectively). TBARS values of all samples were < 0.35 mg MDA/kg and declined after month 0 indicating that these products were oxidatively stable. Overall, adding roe to these products lightened them and increased fibrous texture. Samples containing sockeye salmon roe had stronger salmon flavor. Once retort processed, these products were quite stable in terms of color, odor, and TBARS. Potential nutrient contributions of this type of product to the infant diet warrant additional research.

Keywords: acceptability, baby food, color, salmon roe, sensory

Introduction

The salmon industry in Alaska is in transition due to the increase in the availability of cheaper farm-raised salmon. This has resulted in a loss of market share for Alaskan salmon and a large decrease in total harvest value. In 2007, nearly 500000 metric tons of Alaskan salmon valued at 420 million dollars were harvested (ADFG 2007).

For producers of agricultural commodities to profit, outlets through direct distribution of fresh products (fish, chicken, and so forth) or demand for these raw materials for further processing by food companies must be continuous. When other new products enter the market taking away market share, it becomes necessary for individual commodities to become actively engaged in market expansion. For raw materials demand to increase, food companies must grow continue to profit, by: (1) expanding into new geographic markets, (2) taking market share from competitors by increasing market penetration, or (3) developing new products that can replace those whose profitability is waning. The current project targets all three in addition to offering a potential new use for salmon roe.

A specific "market need" is a prerequisite to new product success.

Fish is low in saturated fats and contains the omega-3 fatty acids (essential), docosahexaenoic acid (DHA), and eicosapentaenoic acid (EPA), which play a significant role in brain growth and visual acuity. Maturation of the visual system of healthy infants improves with a continued supply of DHA from both human milk and DHA-enriched infant foods well into the 1st year of life (Hoffman and others 2004). Fish consumption at least twice a week is recommended for both adults and children (AMA 2007; Gerber 2007). Children weaning off breast milk or formula (both of which are good sources of omega-3 fatty acids) are unlikely to consume enough fish, eggs, or nuts to fill the gap (Gerber 2007).

Salmon is a good source of the omega-3 fatty acid, DHA. The newborn infant's brain is 50% DHA; however, it is unable to synthesize this compound from alpha-linolenic acid in sufficient amounts to ensure an adequate supply to the developing neural tissues. To provide for the needs of the developing brain, The World Health Organization recommends that infant diets (formulas) provide 40 mg of DHA/kg body weight. This recommendation provides additional impetus for developing infant foods from roe from cold water fish such as salmon (FAO 1994).

Salmon roe contain approximately 50 to 3000 IU/g vitamin A and 5-25 IU/g vitamin D (Bledsoe and others 2003). Salmon roe contain significantly more DHA and EPA than fish oils from tuna and sardines and are more oxidatively stable, most likely because of the phospholipid content (Moriya and others 2007). Vitamin D is found naturally in significant quantities only in fatty fish and fish oils, liver, and fat from aquatic mammals, and chicken eggs fed vitamin D. The American Academy of Pediatrics has recently doubled the recommended dietary intake of vitamin D for infants, children, and adolescents to 400 UI/d (Wagner and Greer 2008).

While incorporating roe into baby food products could potentially increase the nutritive value of these products, retort processing can be expected to alter salmon-based food products (Kristinsson and others 2009; Ramamoorthi and others 2009). Similar to salmon flesh, roe are heat labile and also undergo irreversible protein denaturation at 70 to 80 °C resulting in loss or dulling of the characteristic color. While this may have no effect on the protein quality or digestibility, changes in the tertiary structure that affect sensory quality may affect the feasibility of roe inclusion in the product. The suitability of roe from red and pink salmon for this application is unknown. This study examines 6 combinations of retort processed salmon and roe baby food products designed to meet the Food and Drug Administration (FDA 1999) definition of a toddler "high meat dinner" (at least 26% salmon; 9 CFR 381.117[d])

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in terms of sensory characteristics, visually and instrumentally measured color, pH, and water activity.

Materials and Methods

This experiment was designed as a randomized complete block with 6 treatment combinations and 4 replications. Treatment combinations included baby food formulations from sockeye salmon (puree, puree + chunks, puree + red row, puree + red row + chunks, puree + pink row, puree + pink roe + chunks). Physical and sensory characteristics of the products were determined within 48 h of product manufacture for the descriptive study. In the 2nd study, storage stability (6 mo) based on quality characteristics was determined

Sample manufacture

Sockeye salmon was chosen for formulation of the base puree to remove the undesirable characteristics (excessive lightening, off flavor development) found in pink salmon formulations in an earlier study (DeSantos 2009). Wild sockeye (red) salmon (*Oncorhynchus nerka*) were processed by Ocean Beauty Seafoods LLC (Seattle, Wash., U.S.A.). Bone-in fillets (400 to 600 g) were individually quick-frozen, shipped (frozen) to the Univ. of Illinois (Urbana-Champaign, Ill., U.S.A.), and stored at –28 °C until use. Frozen salmon was thawed under controlled conditions (4 to 6 °C) for 2 d prior to baby food manufacture. Baby food was manufactured by combining salmon, water and starch, and roe from red or pink salmon (*Oncorhynchus gorbuscha*) such that 8% of the puree comprised salmon roe (Table 1).

Thinly sliced fillets (2 to 3 cm) and salmon roe were cooked for 3 min in boiling water, and homogenized with a KitchenAid blender (Pro-line, KitchenAide Counter Top Products, St. Joseph, Mo., U.S.A.) at "high" setting for 90 s. Organic Corn Starch (Natl. Starch-Food Innovation, Bridgewater, N.J., U.S.A.) was added during the last 30 s of blending. The product was hot-filled into glass containers (180 mL; 100 mm height, 65 mm width—Jarden Home Brands, Daleville, Ind., U.S.A.) and closed using 2-piece metal vacuum-sealable lids to yield approximately 170 g of product per container. For chunked formulations, preweighed raw salmon chunks (40 to 70 mm) were added to base puree at a ratio of 25% chunks/75% puree (by weight).

Heat penetration studies were conducted with the target of a 12 D reduction of *Clostridium botulinum*. The temperature distribution during thermal processing was assessed using temperature proves inserted into the middle and at the bottom of the containers. The temperature was measured at 1-min intervals and temperature distribution was plotted. Based on the heat penetration results and known times to inactivate *Clostridium sporogenes SC220-4*, the thermal process time was calculated for the baby food (Lynt and others 1981; Myseth 1985; BAM 2001; Ocasio 2008). To build sufficient pressure in the retort to reach 121 °C took 5 min.

The time was calculated to produce a 5 log reduction of *C. sporogenes* based on the time required for samples to attain the required temperature (118 to 121 °C) at the cold point (based on heat penetration studies) plus known times to achieve a 1 log reduction (BAM 2001; Ocasio 2008). Pressure was released over a 13 min period. Containers of baby food products were thermally processed at 118 to 121 °C for 55 min in a steam-jacketed vertical still retort (Model nr AA3152, Food Machinery and Chemical Corp., Hoopeston, Ill., U.S.A.) then cooled to room temperature by pumping potable water (25 °C) through the retort for 10 min after steam was released.

Descriptive analysis

Twelve young experienced adults (<35 y) were trained around a large circular table over four 2-h sessions. Initially, they evaluated salmon and commercial infant food samples (Nature Goodness Stage 2 "Chicken and Chicken Gravy" and "Beef and Beef Gravy," Del Monte Foods, San Francisco, Calif., U.S.A.), and described the sensory characteristics of the products. They were then familiarized with the sensory attributes of salmon (pureed and canned), and provided with terminology and definitions (Prell and Sawyer 1988), to assist in refining a set of descriptive parameters for odor, flavor, aftertaste, and texture. This was accomplished via open discussion with the guidance of a panel leader to establish agreement on characteristics (Vaisey and others 1971). After attributes of interest were selected, various products were presented to the panel for selection of reference standards. Salmon samples and standards were evaluated and panelists assigned standards to locations on the 15-point continuous line scale (0 = none; 15 = extreme) for each characteristic (Table 2).

From the 12 trained panelists, 8 (7 female and 1 male, ages 21 to 35) were selected (based on sensitivity, agreement with group mean scores and availability for all sessions) to evaluate the salmon products. Standards were prepared and capped in 60 mL portion cups at least 1 h before evaluation. Prior to presentation to the sensory panel, samples (approximately 20 g) were heated in a water bath (60 °C) to an internal temperature of 45 °C. Internal temperature was monitored with a Digi-Sense Scanning Thermometer (Cole Parmer Instrument Co., Model 92000-00, Singapore) using copper constantan thermocouple wires inserted into the geometric center of the sample. Samples were presented in random order, in lidded cups labeled with 3-digit random numbers. Panelists were seated at long tables facing the wall to limit interaction during evaluation. The blinds were drawn to eliminate the effects of extraneous light (over and above the fluorescent light provided). Unsalted crackers and water were provided for cleansing the palate between samples. Reference standards were provided at all sessions.

Judges evaluated the visual color of samples using standards shown in Table 3 selected in the same fashion as flavor standard. Eight samples were presented to each panelist during each of 4 (replicate) sessions for evaluation against a white background under fluorescent light (GE warm white, 3013 lux, General Electric, Fairfield, Conn., U.S.A.). During a single session, samples were evaluated in 2 sets with 10 min between sets. During each set, odor, taste, and texture were evaluated first. Color was then evaluated to prevent bias due to visual appearance.

All treatment combinations (puree, puree + chunks, puree + red row, puree + red row + chunks, puree + pink row, puree + pink

Table 1 — Composition of salmon baby food formulations containing salmon roe.

Percent weight in formulation (wet basis)	Ingredients						
	Salmon muscle	Salmon roe	Water	Corn starch	Puree formulation	Salmon muscle chunks	Total
Base puree	32	8	58	2	100	0	100
Chunked variations					75	25	100

Table 2—Sensory standards and scale locations used for salmon baby food products.

Sensory	Standard	Ref score
Odor		
Salmon	*Member's Mark*® (Sam's West, Inc., Bentonville, Ark., U.S.A.) canned Atlantic Salmon fillets (skinless, boneless)	9
Sweaty	0.1% (w/v) *Special Kitty* Premium Cat Food (Walmart, Bentonville, Ark. U.S.A.), ground and dispersed in dH_2O	9
Cooked egg	Freshly boiled white (chicken) egg	7.5
Sweet[a]	10 mL Pepsi	9.0
Ocean[a]	Live sand under water from marine fish tank, Leisure Time, Champaign, Ill., U.S.A.	7.5
Earthy[a]	5 g fresh shiitake mushroom	7.0
Flavor		
Salmon[b]	Salmon chunks baked at 210 °C (10 min) and 60 °C for 10 min	6
Bitter[b]	*Schweppes* (Dr Pepper/Seven Up Inc., Plano, Tex., U.S.A.) tonic water diluted to 25%	8
Savory[b]	Broth from salmon chunks cooked in aqueous solution of NaCl (1%) and monosodium glutamate (0.5%)	10
Metallic[b]	0.01% ferrous sulfate (Walgreen Co., Deerfield, Ill., U.S.A.) dispersed in dH_2O (coating removed)	12
Sweet[b]	Boiled (chicken) egg albumin	7.5
Texture		
Mouth-drying[b]	0.08% aqueous solution of grape seed extract (ActiVin, SJVC, San Joaquin Valley, Calif., U.S.A.)	7
Fibrous[b]	Horseradish sauce	9
Chunk chewiness[b]	Salmon chunks baked at 210 °C (10 min) and 60 °C for 10 min	10
Viscosity[b]	Gulden's Spicy brown mustard (ConAgra Foods, Omaha, Nebr., U.S.A.)	7

[a]Used for storage study only.
[b]Used for descriptive study only.

Table 3—Visual color standards used for evaluating salmon baby food products.

Color chip	Scale position	L^* value	a^* value	b^* value
Pink scale				
Baby's breath 93101[a]	1	91.53	−0.54	9.68
Pink thread 93102[a]	5	89.59	2.37	11.44
Mermaid 93103[a]	10	85.14	7.11	15.19
Salmon A27-3[c]	15	80.85	14.46	22.30
Yellow scale				
Orange sparkle 2007-4C[b]	1	93.26	−4.36	18.73
Almond whip 2008-4C[b]	3	92.03	−3.81	26.33
Honey pecan 2008-4B[b]	8	87.34	−0.48	36.42
Almond butter 3001-4A[b]	15	83.68	2.92	40.31
Cream-brown scale				
Sand dune 267-1[d]	3	88.73	0.38	19.15
Vanilla tan 267-2[d]	7	83.30	4.43	24.78
Boulder buff 267-3[d]	10	77.69	8.23	29.36
Sunstone 267-4[d]	14	69.32	13.39	33.66

[a]Lowe's Companies Inc. *American Tradition,* North Wilkesboro, N.C., U.S.A.
[b]Walmart *ColorPlace,* Bentonville, Ark., U.S.A.
[c]Lowe's Companies Inc. *Olympic Paints*, North Wilkesboro, N.C., U.S.A.
[d]Lowe's Companies Inc. *Valspar*, North Wilkesboro, N.C., U.S.A.

roe + chunks) were first evaluated for odor and taste characteristics. Samples were then presented under fluorescent light (GE warm white, 3013 lux, General Electric) against a white background. Visual color was evaluated following odor, taste, and texture evaluations so as to prevent bias due to visual appearance.

Water activity, pH, viscosity, and instrumental color

Water activity (a_w) was determined using an AquaLab CX2 meter (Decagon, Pullman, Wash., U.S.A.). The pH was determined by placing the electrode of an Accumet pH meter (Accumet model 15, Fisher Scientific, Pittsburgh, Pa., U.S.A.) directly into baby food samples (22 °C). Viscosity was determined on the red salmon puree used as the base for all the baby food products at 20 rpm using spindle 4 in a Brookfield Viscometer (Brookfield SP Model LR 99102, Brookfield Engineering Laboratories Inc., Middleboro, Mass., U.S.A.). Instrumental color was determined using a LabScan 6000 spectrocolorimeter (Hunter Labs, Reston, Va., U.S.A.) Reflectance was determined over the 400 to 700 nm range using illminant D65 to calculate CIE L^*, a^*, and b^* values, hue angle (arctan (b^*/a^*), and chroma ($[a^{*2} + b^{*2}]^{1/2}$) (CIE 1978).

Storage study

Samples were formulated and processed as previously described then stored at room temperature (22 °C) in the dark for 6 mo. Samples were removed from storage monthly and evaluated by instrumental, chemical, and sensory means. These samples were then discarded. Water activity, pH, and instrumental color were determined. Sensory judges were trained as previously described to evaluate odor using the designated sensory terms in Table 2 and visual color using the scale shown in Table 3.

Thiobarbituric acid-reactive substances (TBARS) were determined after each month of storage using the cold extraction method described by Miller (1998) based on the methods developed by Tarladgis and others (1960) and Witte and others (1970). Absorbance was determined spectrophotometrically (Beckman Coulter DU® 640, Inc., Fullerton, Calif., U.S.A.) at 530 nm. Concentration of malondialdehyde (MDA) was calculated from a standard curve using solutions of tetraethoxypropane (TEP; 0 to 10 nm MDA/mL). The equation obtained from the curve was $y = 0.0819\,x + 0.0055$ ($r^2 = 0.999$) where y is the absorbance of the sample extract and x is the concentration of MDA. Malondialdehye recovery was computed using the TEP-spiked samples. Each sample was analyzed in duplicate. Results are expressed as mg malondialdehyde/kg sample.

Descriptive data from the 1st part of the study were treated as a 2 (puree or chunk) by 3 (no roe, with pink roe, or with sockeye roe) factorial design, and analyzed using the Mixed Models procedure (SAS 2002) to determine main effects and interactions. Effects were considered significant at $P < 0.05$. Separation of least square means (LSM) was achieved using the Tukey–Kramer post hoc test for multiple comparisons. For sensory data, judges were included as a random effect and experiment replication as a repeated measure. Correlations between instrumental and visual color, and among sensory odor and flavor scores were made using PROC CORR (SAS 2002). All results from the Mixed Models are reported as least squares means of the fixed effects.

Instrumental data and TBARS for the storage study were treated as a 2 (puree or chunk) by 3 (no roe, sockeye, or pink roe) by 7 (storage time) factorial design, and analyzed using the Mixed Models procedure (SAS 2002) to determine main effects and interactions. Effects were considered significant at $P < 0.05$. Separation of LSM was achieved using the Tukey–Kramer post hoc test for multiple comparisons. Sensory data were analyzed as described for instrumental data with the inclusion of judges as a repeated measure. Correlations between instrumental and visual color were made using PROC CORR (SAS 2002). All results from the Mixed Models are reported as LSM of the fixed effects, and standard errors of the mean (SEM) reported for significant measures.

Table 4—Effect of roe and chunks on characteristics of salmon baby food.

	Puree			Chunk			
Characteristic	No roe	Pink roe	Sockeye roe	No roe	Pink roe	Sockeye roe	SE
Instrumental							
L^* value	61.30^{b}	68.39^{a}	68.67^{a}	63.90^{b}	67.08^{a}	68.32^{a}	0.59
a^* value	19.57^{a}	15.16^{c}	13.44^{cd}	15.53^{bc}	14.86^{c}	12.67^{d}	0.43
Hue angle	57.36^{b}	62.18^{a}	63.16^{a}	61.98^{a}	61.73^{a}	63.16^{a}	0.70
Sensory							
Bitter flavor	1.79^{b}	1.69^{b}	1.16^{b}	3.18^{a}	2.09^{ab}	1.08^{b}	0.56
Metallic flavor	1.91^{ab}	2.13^{ab}	1.93^{ab}	2.74^{ab}	2.86^{a}	1.21^{b}	0.58
Mouth-drying	2.47^{c}	6.05^{a}	4.28^{b}	3.48^{c}	4.31^{b}	3.69^{c}	0.64
Visual pink color	10.03^{a}	6.11^{b}	5.78^{b}	8.72^{a}	7.02^{b}	6.13^{b}	1.07

Scale: 0 = none, 15 = extremely intense.
^{abcd}Means within a row with like superscript letters do not differ ($P \leq 0.05$).

Results

Characteristics of raw materials

Raw bone-in salmon was 73% to 73.6% moisture, about 1.7% fat, had an L^* value of 67.4, an a^* value of 34.8, b^* value of 36.2, and chroma of 50.2 (data not shown).

Descriptive study results

The pH ranged from 6.47 to 6.84 among the 6 products formulated (data not shown). Formulations containing pink roe were similar in pH to those without roe (6.7; SEM = 0.02), and were slightly higher than those formulated with sockeye salmon roe (6.5). The water activity of all treatment combinations was 0.99. The viscosity of the red salmon puree that was used as the baby food base for all treatments was 3800 cP. Viscosity of roe-containing samples was above the upper limit of measurement of the viscometer.

There was a significant roe type (red compared with pink) by product type (chunk compared with puree) interaction for L^* and a^* values, hue angle, bitter, metallic and mouth-drying flavors, and visual pink color (Table 4). The addition of roe had a direct effect on L^* values of the pureed baby foods. Samples containing roe had higher L^* values (lighter) than those without roe (Table 4), regardless of the type of roe added. This lightening may result from the increase in fat content of the formulation. The fat content of the sockeye salmon puree was about 0.85 g/100 g (Brewer 2008) while that of roe-containing samples contained 1.4 to 2.69 g/100 g. Fat content has been shown to affect the color of salmon products (Christiansen and others 1995).

Products containing roe were also less red (by approximately 3 to 4 a^* units) than formulations without roe, with no clear difference due to roe source (red compared with sockeye). Visual pink color followed the same trend; judges scored salmon products with roe as less pink than those without roe, and visual pink scores for base puree (without roe) averaged at least 1 unit (on the 15 cm line) higher (pinker) than the chunked product without roe. Hue angles were lowest (closer to the true red axis of the color scale) for sockeye salmon puree with neither roe nor chunks, and were similar for all other products. There was significant roe type (red compared with pink) by product type (chunk compared with puree) interaction for mouth-drying mouthfeel (Table 4). Pureed samples without roe had the lowest mouth-drying scores (2.47 to 3.48) while the puree with pink roe had the highest (6.05). Metallic flavor was most prominent in the chunked product containing roe from pink salmon and lowest in chunked product containing roe from sockeye salmon (Table 4). While the presence of roe appeared to attenuate the bitter taste, it did not have the same effect on metallic flavor.

Samples with roe were less bitter (Table 4). Lawless and others (2003) reported that tastes associated with calcium chloride were largely suppressed when calcium was combined with larger organic ions such as lactate, gluconate, or glycerophosphate. It is possible that the addition of roe to the base formulation moderated the bitter taste detected either through an association of bitter components with calcium or by attenuating the taste response due to an increase in lipid compounds from the roe (Lawless and others 2003). Not unexpectedly, bitter flavor was negatively correlated with sweet flavor ($r^2 = -0.82$; data not shown).

Roe from pink salmon is yellow while that from sockeye salmon is a very vivid, dark orange-red color. The effects of inclusion of roe from various sources were apparent in the instrumental data, especially in the b^* values (yellowness) and chroma (color saturation) of the products (Table 5). The b^* value of samples (both puree and chunk) with sockeye roe (25.8) was lower than that of samples with pink roe (28.2), and both were lower than that of the control (29.9). Chroma followed a similar trend.

The sensory panel's perception of yellowness and cream-brown color also varied due to the inclusion of roe; samples with roe were scored significantly lower on the visual yellow intensity scale (Table 5). However, the panel did not differentiate between samples with pink compared with sockeye roe with respect to visual yellow or cream-brown colors. L^* value and hue angle were inversely correlated with visual pink, yellow, and cream brown colors, while a^* and b^* values were positively correlated with all visual characteristics (Table 5). The pigments in salmon eggs are heat-labile. The proteins denature at 70 to 80 °C (Bledsoe and others 2003). However, from these color observations, it is evident that their characteristic colors are apparent even after the disruption of cells that occurs during homogenization and the protein denaturation that occurs during thermal processing. Fibrousness differed due to the presence of roe; formulations with roe, both pink, and sockeye, were

Table 5—Effect of roe on characteristics of salmon baby food.

Characteristic	Control (no roe)	With pink roe	With sockeye roe	SEM
Instrumental				
b^* value	29.87^{a}	28.15^{b}	25.81^{c}	0.24
Chroma	34.67^{a}	31.91^{b}	28.93^{c}	0.29
Sensory				
Salmon flavor	4.37^{b}	4.42^{b}	5.38^{a}	0.63
Sweet taste	3.35^{b}	3.12^{b}	4.82^{a}	0.73
Fibrousness	2.33^{b}	4.81^{a}	4.21^{a}	0.45
Chunk chewiness	2.32^{b}	3.19^{a}	2.55^{b}	0.47
Yellow color	9.05^{a}	6.15^{b}	5.21^{b}	0.95
Cream-brown color	8.07^{a}	6.25^{b}	5.54^{b}	0.51

Scale: 0 = none, 15 = extremely intense.
^{abcd}Means within a row with like superscript letters do not differ ($P \leq 0.05$).

Table 6 – Effect of inclusion of chunks on characteristics of salmon baby food.

Characteristic	Baby food samples: Puree only	Baby food samples: Puree + chunks	SEM
Instrumental			
b^* value	28.61^{a}	27.24^{b}	0.20
Chroma	32.84^{a}	30.83^{b}	0.24
Sensory			
Salmon flavor	4.31^{b}	5.14^{a}	0.61
Savory flavor	4.80^{b}	5.91^{a}	0.84
Fibrousness	3.41^{b}	4.16^{a}	0.39
Chunk chewiness	0.78^{b}	4.60^{a}	0.45
Cream-brown color	7.00^{a}	6.24^{b}	0.30

Scale: 0 = none, 15 = extremely intense.
^{abcd}Means within a row with like superscript letters do not differ ($P \leq 0.05$) pooled across samples with and without roe.

Table 7 – Effect of storage time on baby food containing roe.

Sensory parameter	Storage time (months): 0	1	2	3	4	5	6	SEM
Sweaty	4.45^{a}	3.90^{ab}	2.38^{b}	3.68^{ab}	3.35^{ab}	2.77^{b}	2.71^{b}	0.41
Cooked egg	5.82^{a}	5.03^{a}	2.57^{b}	3.42^{b}	2.62^{b}	2.58^{b}	2.71^{b}	0.38
Earthy	3.64^{a}	4.45^{a}	2.69^{b}	2.55^{b}	2.76^{b}	2.73^{b}	3.09^{ab}	0.34
Ocean	0.98^{b}	3.70^{a}	2.12^{ab}	2.61^{b}	1.47^{b}	1.92^{b}	2.41^{ab}	0.39
Pink color	4.81^{b}	4.13^{b}	4.31^{b}	4.84^{b}	5.44^{b}	4.89^{b}	8.31^{a}	0.40
Yellow color	2.80^{b}	3.14^{b}	3.44^{ab}	3.94^{ab}	4.91^{a}	4.96^{a}	3.10^{b}	0.41
TBARS	0.23^{a}	0.14^{b}	0.13^{b}	0.14^{b}	0.13^{b}	0.13^{b}	0.10^{b}	0.00

Main effects pooled over chunked or puree forms and presence of roe.
SEM = standard error of mean.
^{a,b}Means within a row with like superscripts do not differ ($P < 0.05$).
Scale: 0 = none, 15 = extremely intense.

almost twice as fibrous as formulations without roe (Table 6) but only about half as fibrous as the horseradish sauce used as a reference standard. The chunks contained in the formulations with pink salmon roe had higher chewiness scores (3.2) than those with sockeye roe or no roe (2.3 to 2.6) (Table 5) but these were still very low relative to the reference standard used (baked salmon; scale location = 10).

Salmon flavor was stronger in samples containing roe from sockeye salmon (Table 5). Samples without roe were perceived to be more bitter. Although cooked egg odor did not differ significantly among samples, those with roe had nominally higher scores than those without roe. Samples that were scored higher for cooked egg odor had low scores for bitterness ($r = -0.94$; data not shown).

Inclusion of chunks reduced a^* (redness) and b^* values (yellowness), which reduced chromaticity and increased hue angles (Table 6). This is noteworthy since consumer evaluation during the previous study revealed that chunked products were less visually acceptable than pureed formulations (Desantos 2009).

Including chunks in the baby food product decreased yellowness (b^*) and chroma, and visual cream brown color. Including chunks in the baby food increased salmon and savory flavors and fibrous and chewiness (data not shown). Salmon flavor was correlated with savory flavor ($r = 0.89$), and, to a lesser extent, with chunk chewiness ($r = 0.74$). Bitter flavor was inversely correlated with cooked egg odor ($r = -0.94$). Sweet taste was inversely correlated with bitter and metallic flavors ($r = -0.82$ and –0.92, respectively; data not shown).

Since chunked formulations contained more salmon than the pureed base, addition of chunks would be expected to impact the intensity of salmon odor or flavor.

Storage study results

There were no 2- or 3-way interactions (chunk inclusion, presence of roe, and storage time) for sensory. Salmon and sweetness odor scores were nonsignificant (7.3 ± 0.2, and 2.9 ± 0.2, respectively; Table 7). All visual color measures differed among samples due to the presence characteristics and type of roe in the formulation.

Sweaty odor was most intense in fresh samples (prior to storage) and generally decreased during storage (Table 7). This sweaty odor may be due to 2, 4-heptadienal, a compound identified by Girard and Durance (2000) described as having "fishy" and "catfood" aromas. Cooked egg odor did not differ significantly during the first 5 mo of storage but then declined to a constant value. It was surprising that cooked egg odor was unaffected by inclusion of salmon roe. Earthy odor remained constant during the first 2 mo of the study (>3.6), decreased then returned to approximately the original level at month 6. The ocean odor was an attribute measured for the 1st time in this series of studies of salmon quality characteristics. While ocean odor differed from earthy odor at time 0, this characteristic followed the same trend as earthy odor. Visual pink and yellow color scores were also affected by storage time. In general, visual pink color did not change until after the 5th month of storage when there was a significant increase (from 4 to 5 to > 8; Table 7). Visual yellow color scores increased slightly over time, but after 6 mo, were still comparable with scores at the scores at the initiation of the study.

Storage time appeared to have the least effect on instrumentally measured color of these products (data not shown). L^* and a^* values of samples without roe appeared to be most stable over time, while those of samples containing chunks fluctuated slightly. L^* values of all samples remained between 67 and 70 throughout the storage period. The a^* values of all samples remained between 15 and 18 throughout the storage period. The b^* value of samples without roe were higher at all time periods than those of samples containing roe. In addition, the b^* values of samples without roe appeared to fluctuate more (29 to 32) than those with roe (red roe, 33 to 35; pink roe, 36 to 37). Correlations between visual color and instrumental color were moderate (data not shown). The best correlations were observed between visual cream-brown and L^*, a^*, b^*, and chroma values ($r = -0.80$, 0.75, 0.80, and 0.84, respectively).

TBARS values ranged between 0.1 and 0.35 mg MDA/kg (Table 7). TBARS values of all samples declined after month 2 then stayed fairly constant over the remainder of the storage period. This may be because the initial cooking and retort Chunked formulations generally had higher TBARS values (approximately 0.35) initially but these declined over storage time (data not shown). Reactive substances may have broken down to lower molecular weight compounds over time. Ortiz and others (2009) reported that TBARS of cooked, farm-raised Coho salmon (*O. kisutch*) that had been supplemented with dietary antioxidants varied from 0.5 to 0.8. They did not change significantly in the first 6 mo of frozen storage, nor did a trained panel detect oxidized flavor.

Conclusions

Adding roe to salmon baby food resulted in a lighter, less red product regardless of roe type (pink or sockeye). Formulations with roe were almost twice as fibrous as formulations without roe. Salmon flavor was stronger in samples containing roe from sockeye salmon than in that containing roe from pink salmon. Storage time had small effects on sweaty, cooked egg, earthy, and ocean odors, and pink and yellow visual scores. Visual cream-brown color was well correlated with instrumental color measures. TBARS values remained low (0.1 to 0.35 mg MDA/kg) throughout 6 mo of storage.

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